Probing the Character of the Pygmy Dipole Resonance

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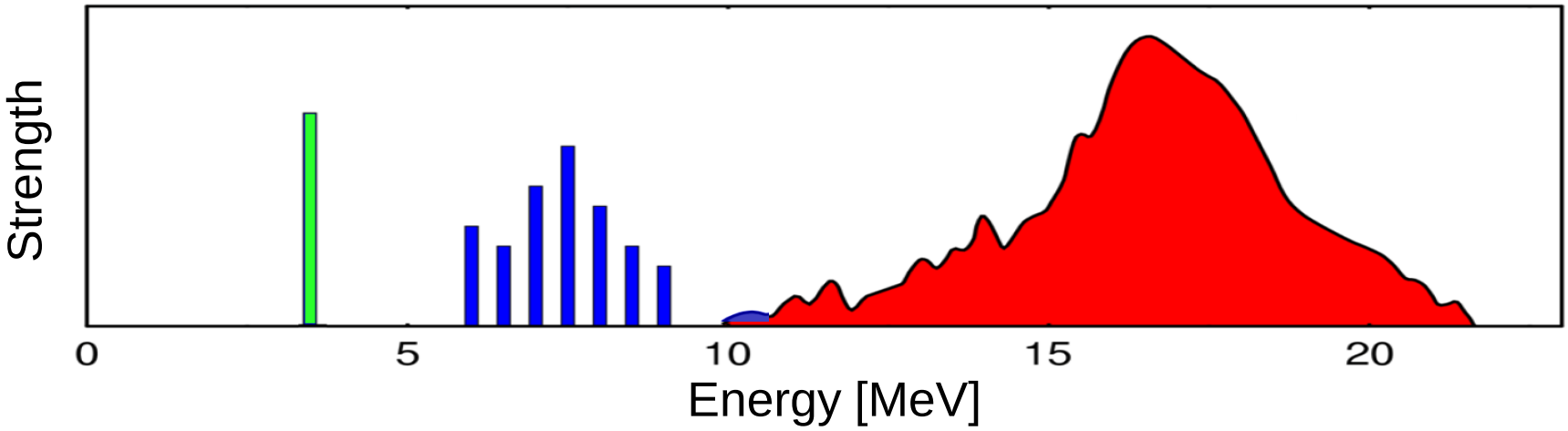
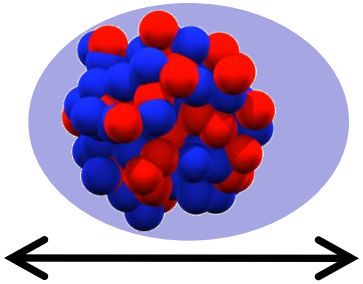
Outline

- Introduction
- Experimental Methods
- Results
  - for ^{94}Mo
  - for ^{48}Ca
- Summary

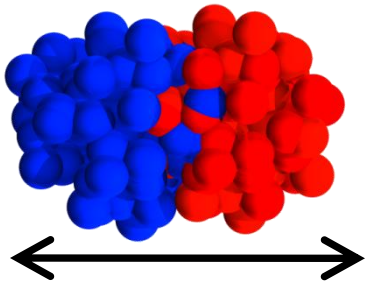
Electric dipole strength in spherical atomic nuclei



Two-phonon state

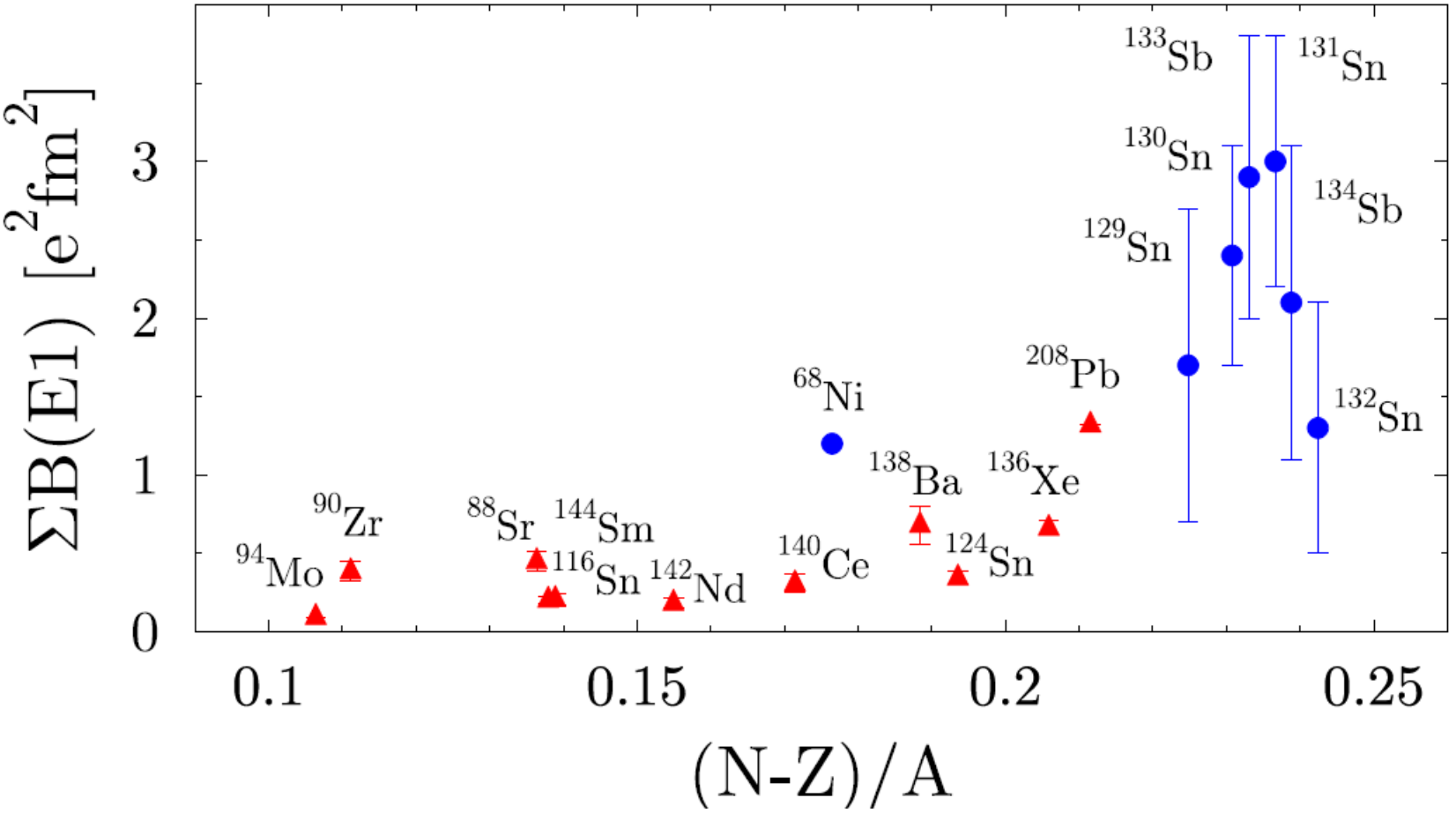


Electric pygmy dipole resonance (PDR)

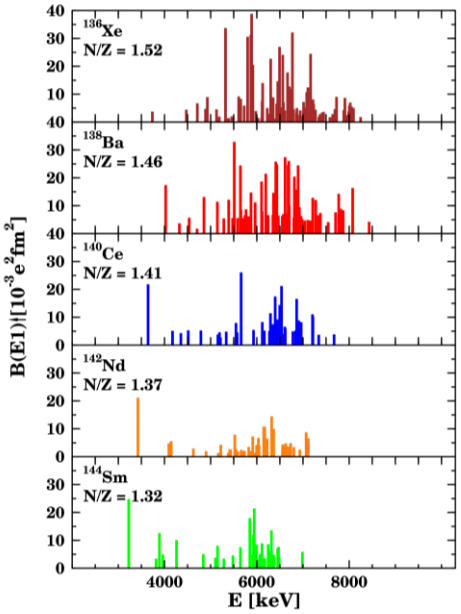


Isovectorial electric giant dipole resonance (GDR)

Summed B(E1) Strength



Splitting of the PDR



- Real photons:

  Strongly fragmented E1 strength

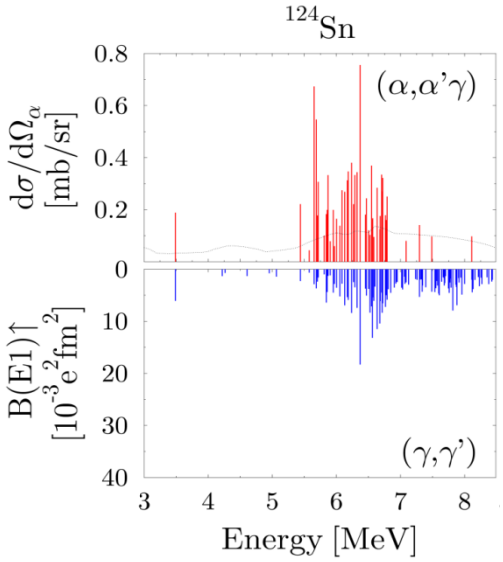
A. Zilges et al., Phys. Lett. B **542** (2002) 43
S. Volz et al., Nucl. Phys. **A779** (2006) 1
D. Savran et al., Phys. Rev. Lett **100** (2008) 232501

- Complementary α particles:

  Splitting of the PDR

  in ^{140}Ce, ^{138}Ba, and ^{124}Sn

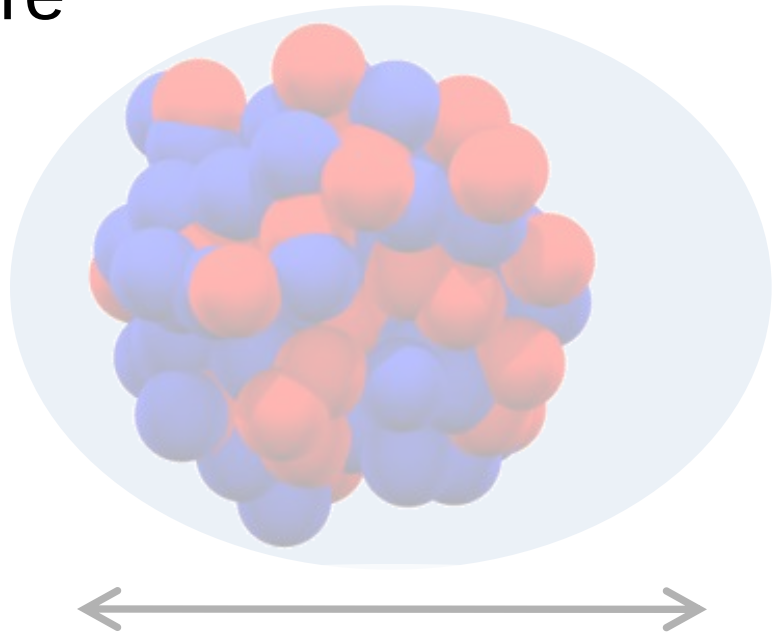
J. Endres, E. Litvinova, *et al.,*
Phys. Rev. Lett. **105** (2010) 212503



Two Nuclei – Two Aspects

- ^{94}Mo
  - Non-magic
  - Near to (sub) shell closure
  - Spherical

Effect of non-magicity?



- ^{48}Ca
  - Doubly-magic
  - Medium-mass region

Evolution of collectivity?

Experimental Methods

Reaction

- (γ,γ')
- Real-photon scattering

Setup

- Darmstadt High-Intensity Photon Setup
- E_γ = 0-10 MeV
- 2 HPGe detectors

Selectivity

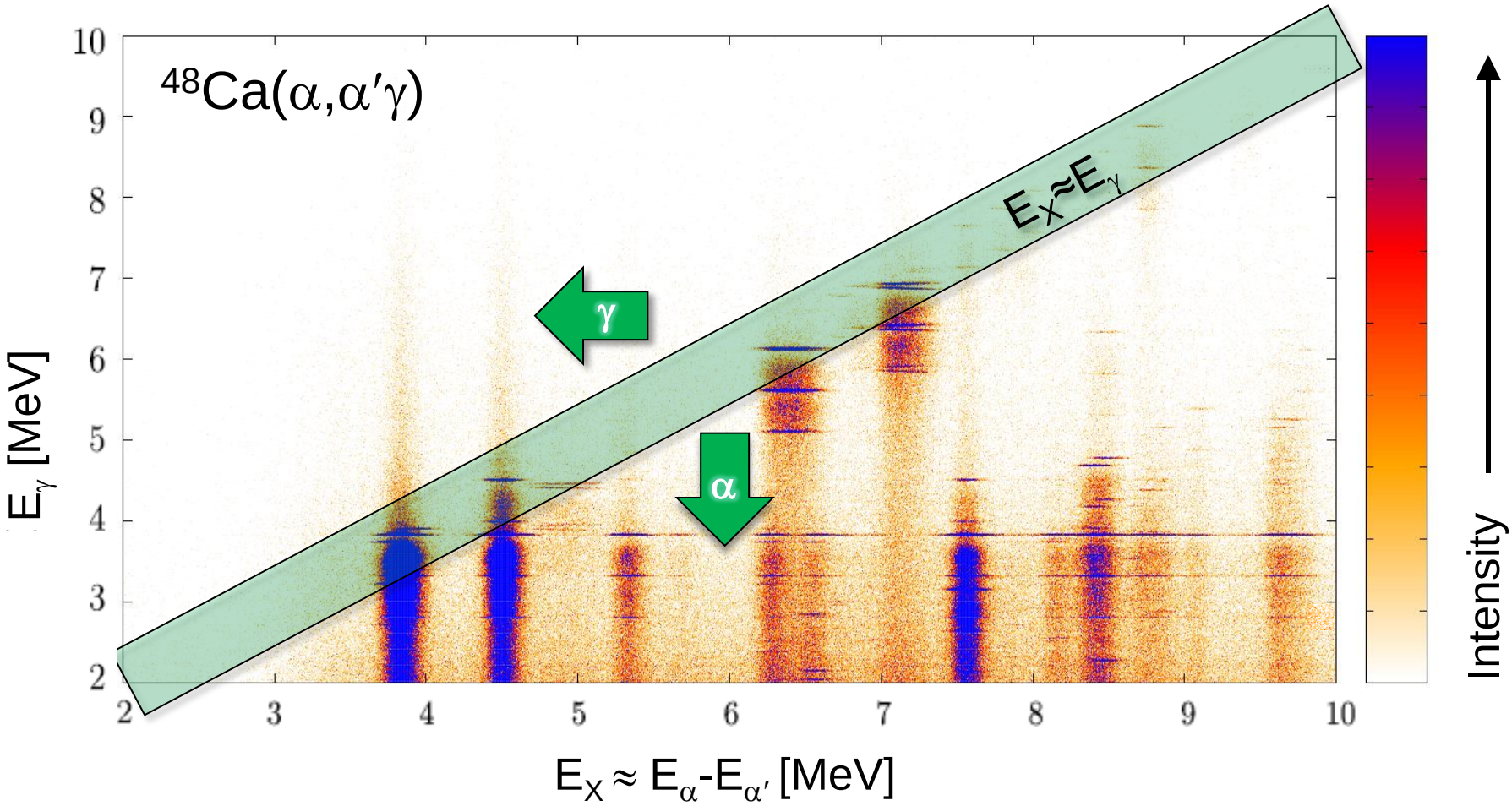
- Mainly E1 from ground state

- $(\alpha,\alpha'\gamma)$
- Inelastic α-scattering with γ coincidence

- Big-Bite Spectrometer at KVI Groningen
- E_α = 136 MeV
- 6-7 HPGe detectors and α spectrometer

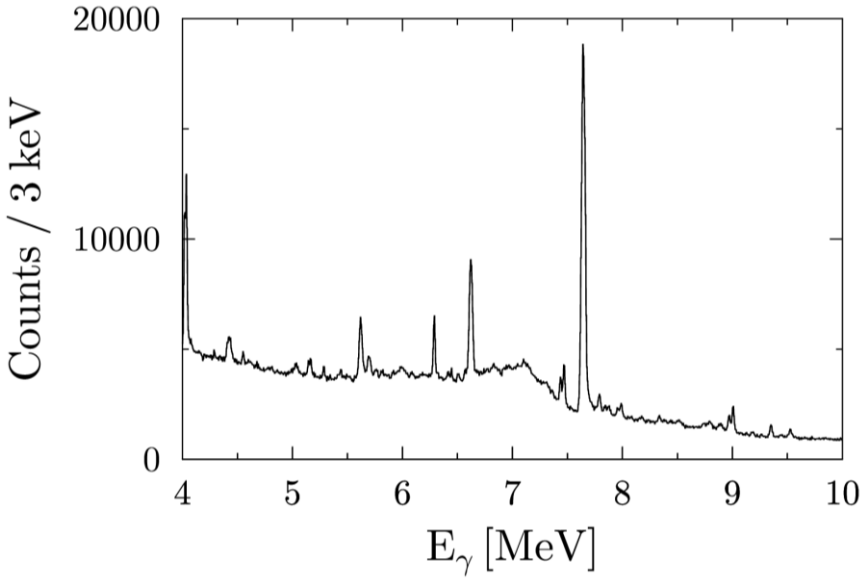
- Mainly low spin from ground state
- Isoscalar probe

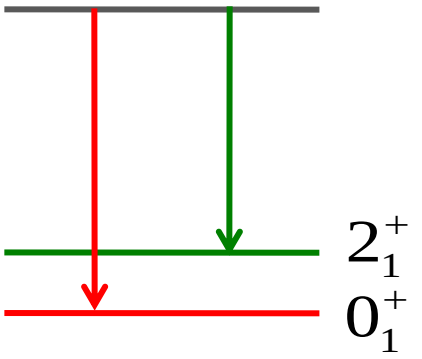
α-γ Coincidence Matrix

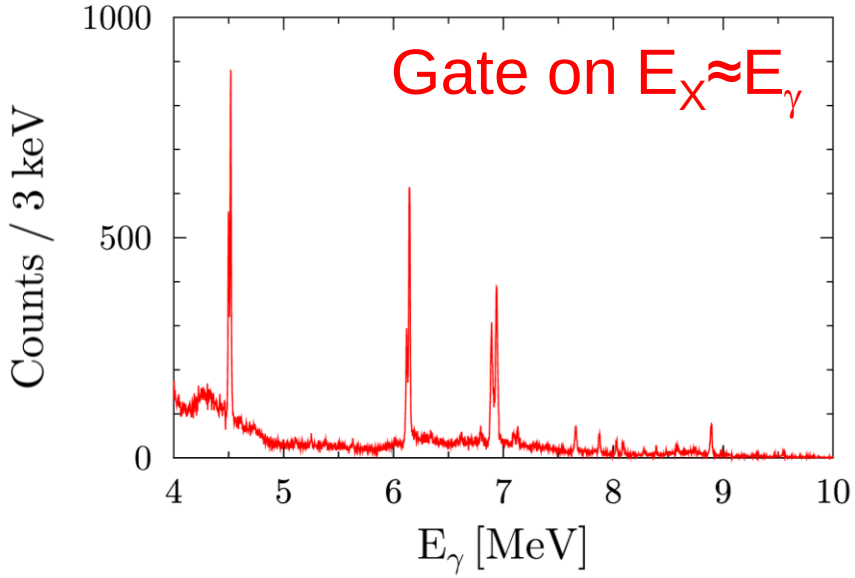


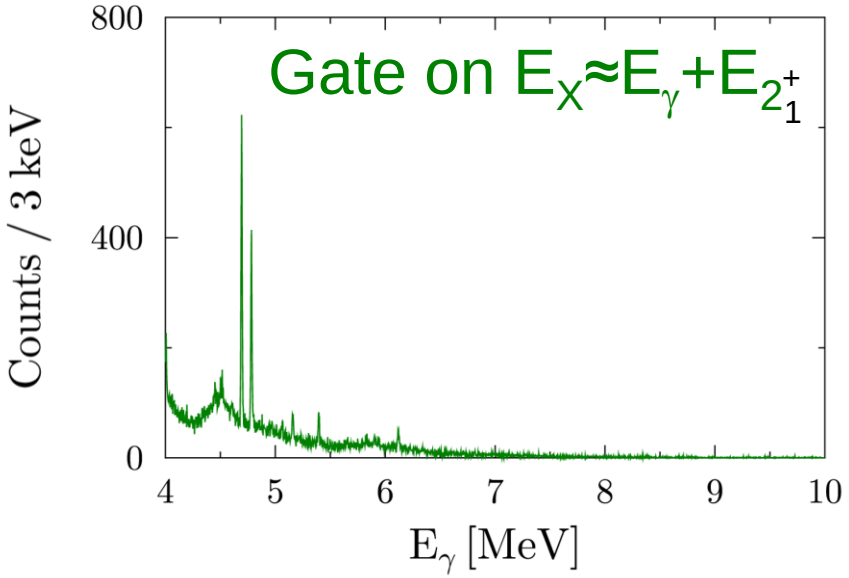
- Energy spectra through projection
- Selecting transitions by setting gates

Selecting transitions – Projected γ spectra

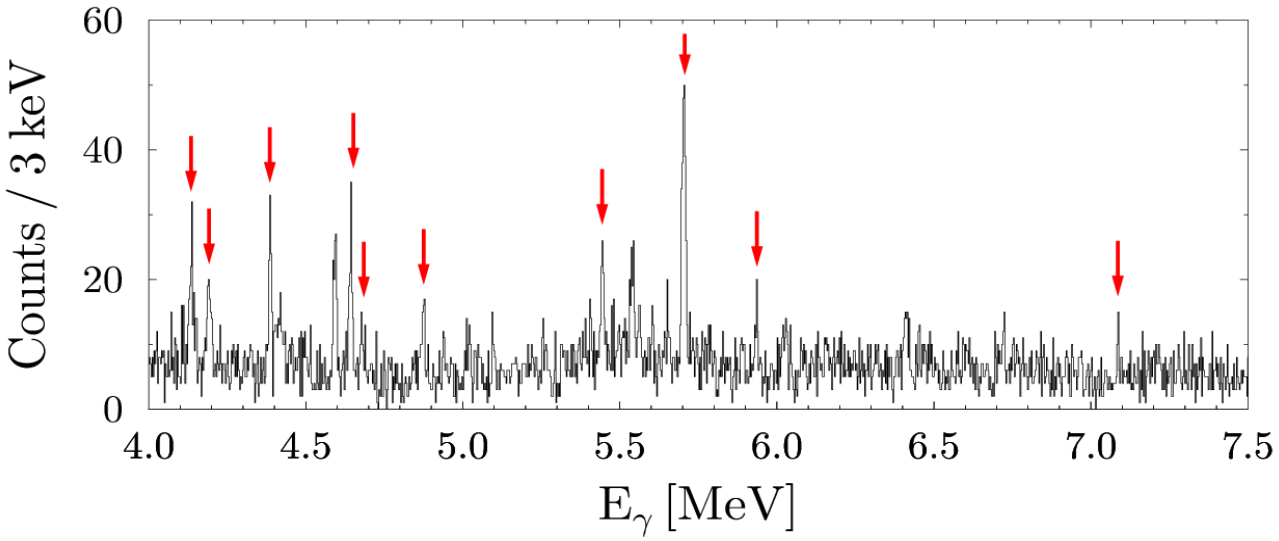






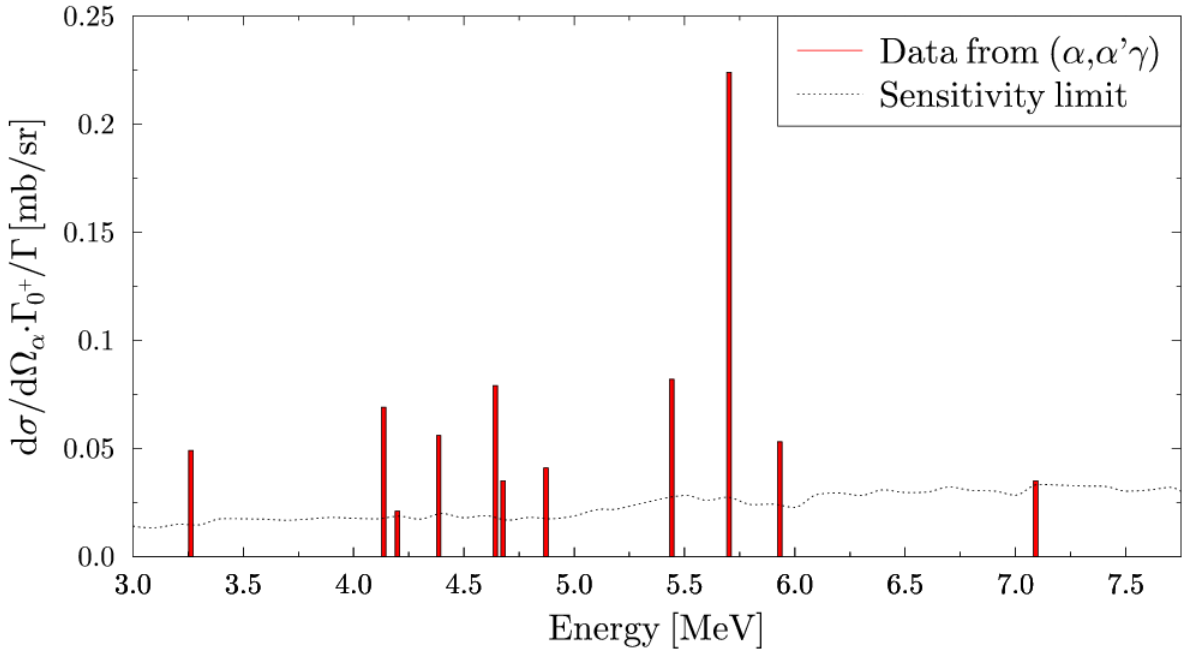


Results for ^{94}Mo

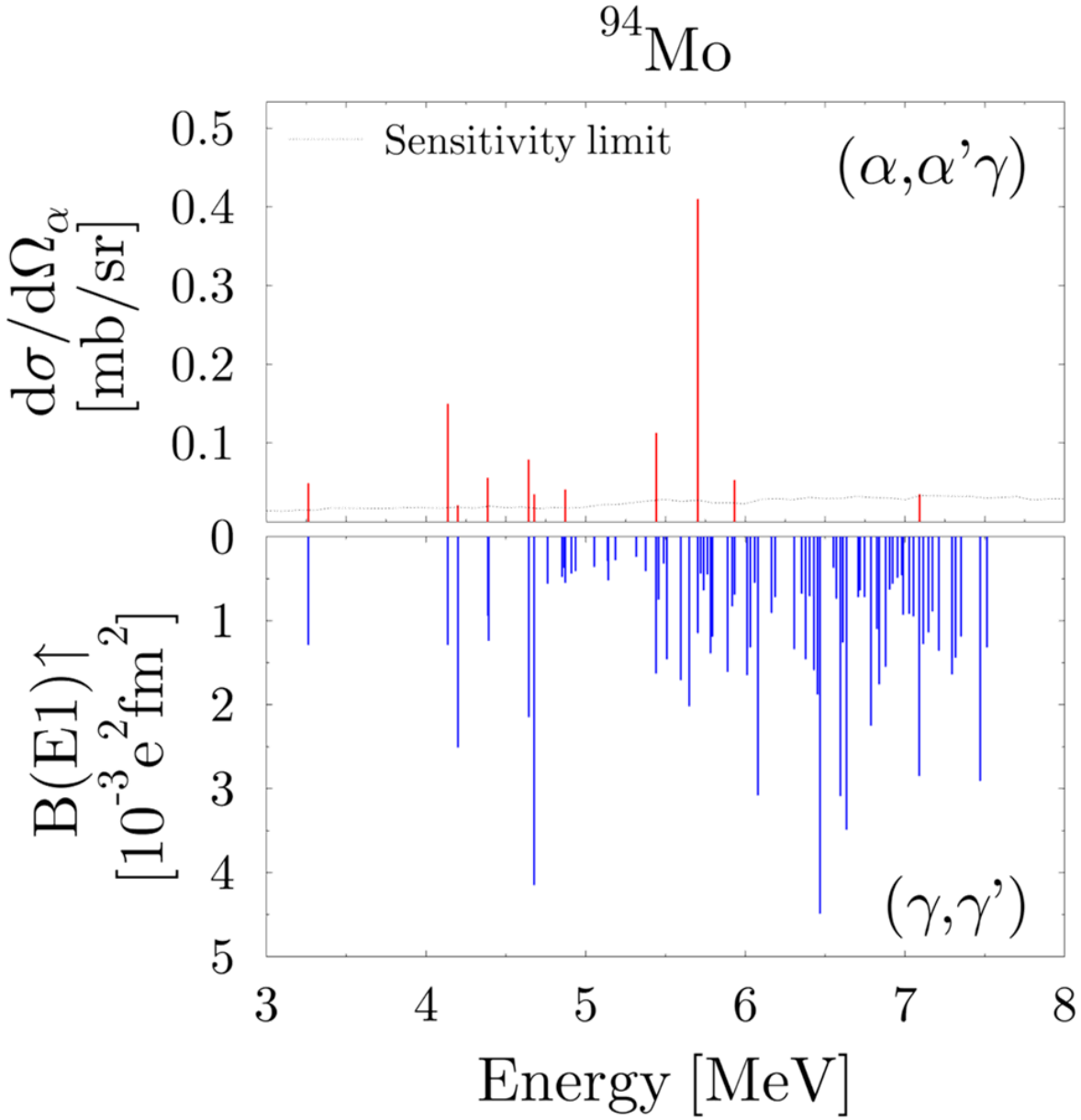


10 lines in the γ spectrum gated on $E_X \approx E_\gamma$

α-scattering cross sections

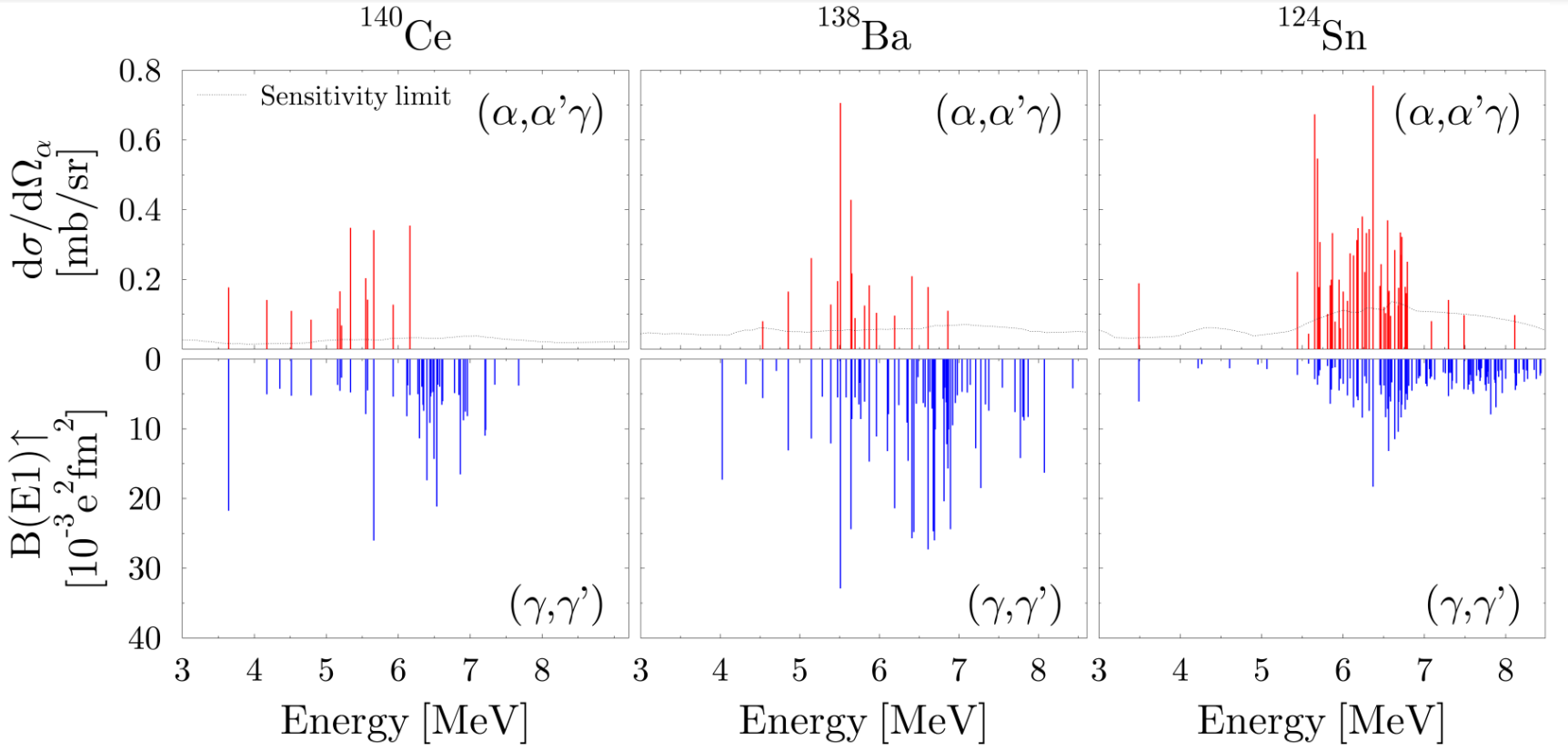


(α,α′γ) and (γ,γ′) in ^{94}Mo



C. Romig, private communication

(α,α′γ) and (γ,γ′) in ^{140}Ce, ^{138}Ba, and ^{124}Sn



D. Savran *et al.*,
Phys. Rev. Lett. **97** (2006) 172502

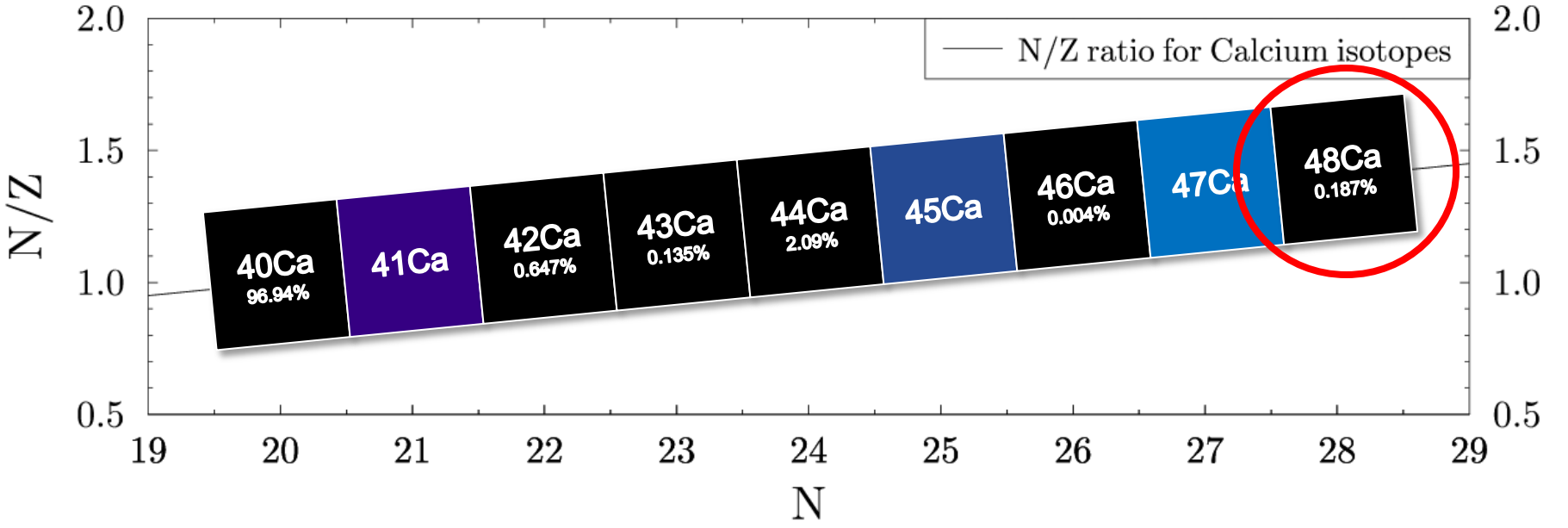
J. Endres *et al.*,
Phys. Rev. C **80** (2009) 034302

J. Endres, E. Litvinova, *et al.*,
Phys. Rev. Lett. **105** (2010) 212503

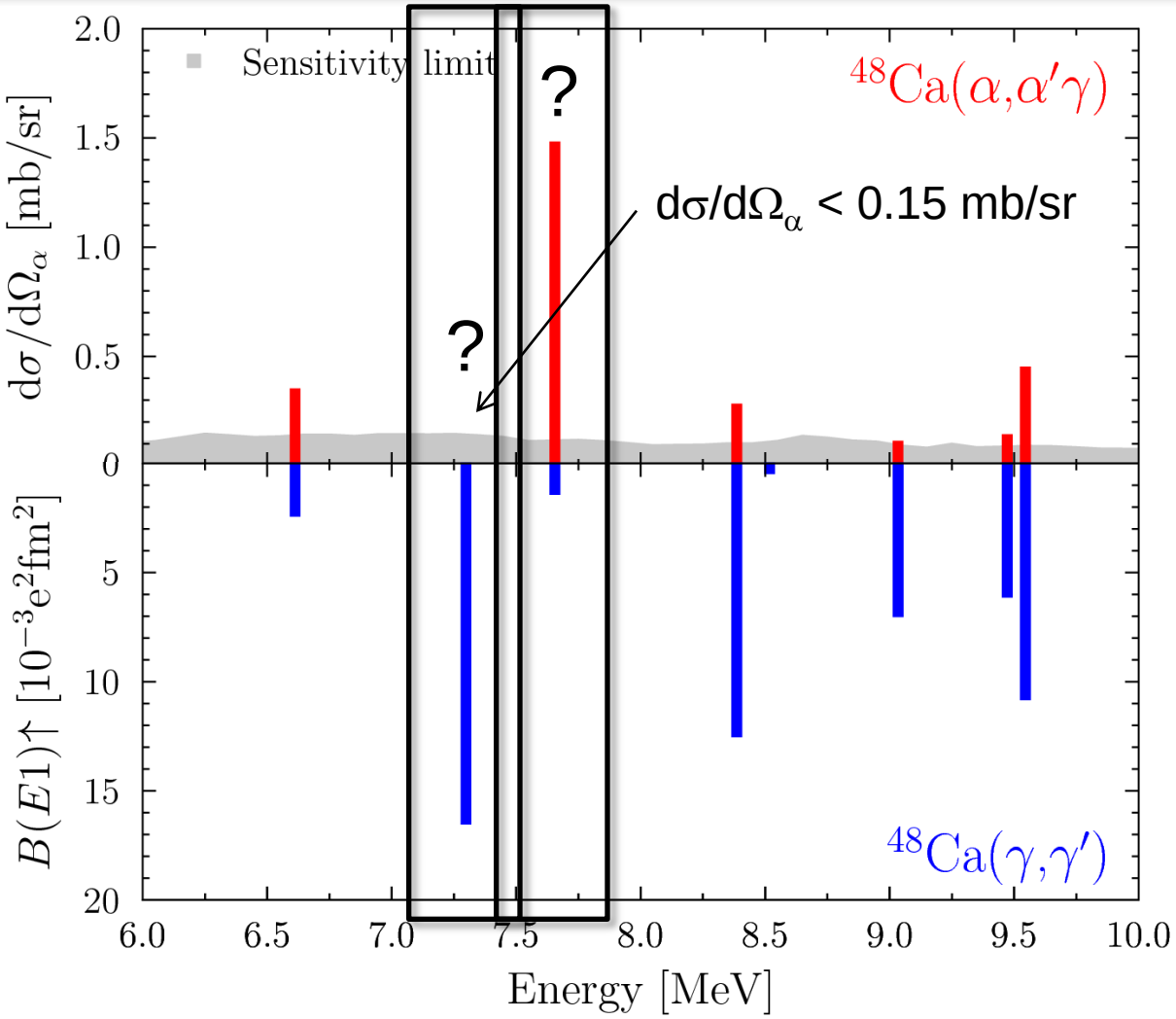
- Splitting of the PDR ➔ due to isospin character
  - low-energy part → (γ,γ′) and (α,α′γ)
  - high-energy part → (γ,γ′) only

Low-Lying Dipole Strength in Lighter Nuclei

- Light-mass nuclei: halo nuclei, single-particle character excitations
- Medium-mass nuclei: development of a more collective dipole-excitation mode?
- Dependence on N/Z ratio in the Calcium chain

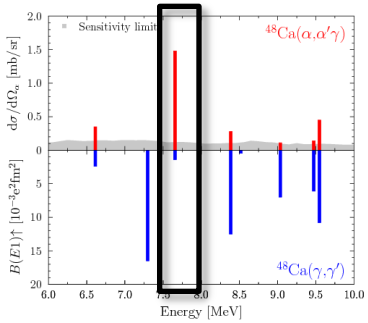


$J=1^-$ states in $(\alpha,\alpha'\gamma)$ and (γ,γ')

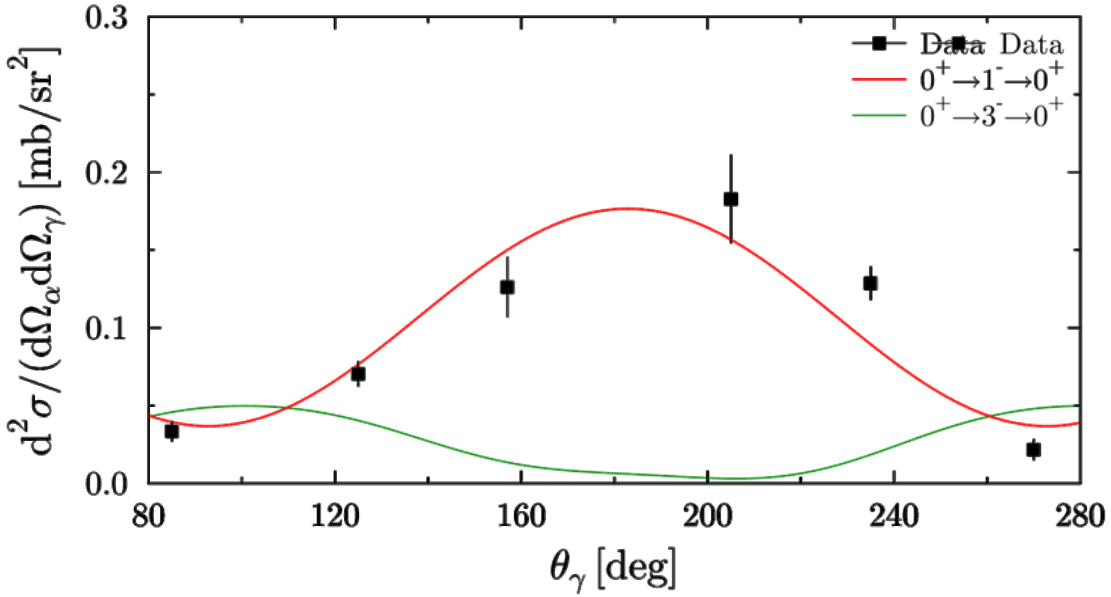


- Strongest state in (γ,γ') at 7.3 MeV is missing in $(\alpha,\alpha'\gamma)$
- Strongest state in $(\alpha,\alpha'\gamma)$ at 7.6 MeV is weak in (γ,γ')

The State(s) at 7.655 MeV



- Known $J^\pi=3^-$ state at 7.651(1) MeV
- Multipolarity of the observed ground-state transition: E1 or E3?
- Double-differential cross section $d^2\sigma/(d\Omega_\alpha d\Omega_\gamma)$ and α-γ angular correlation ➔ Multipolarity

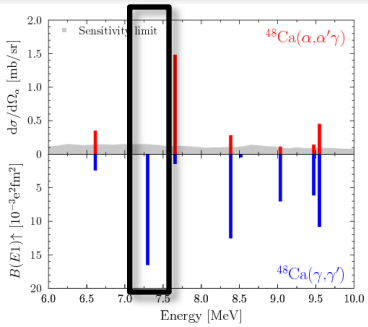


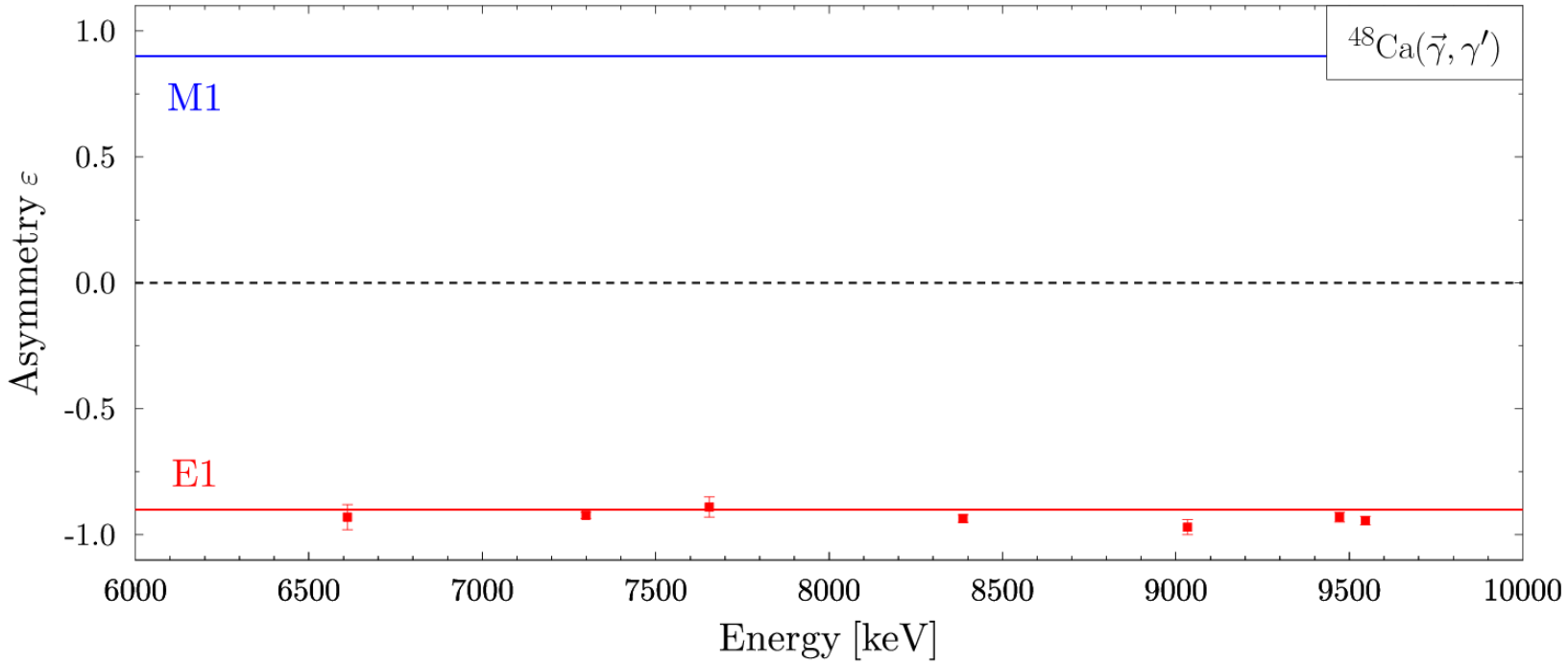
θ_γ: angle of γ-ray emission with respect to the α-beam (position of the 6 HPGe detectors)

Ground state transitions stem from $J^\pi=1^-$ state

Parity Assignments in ^{48}Ca

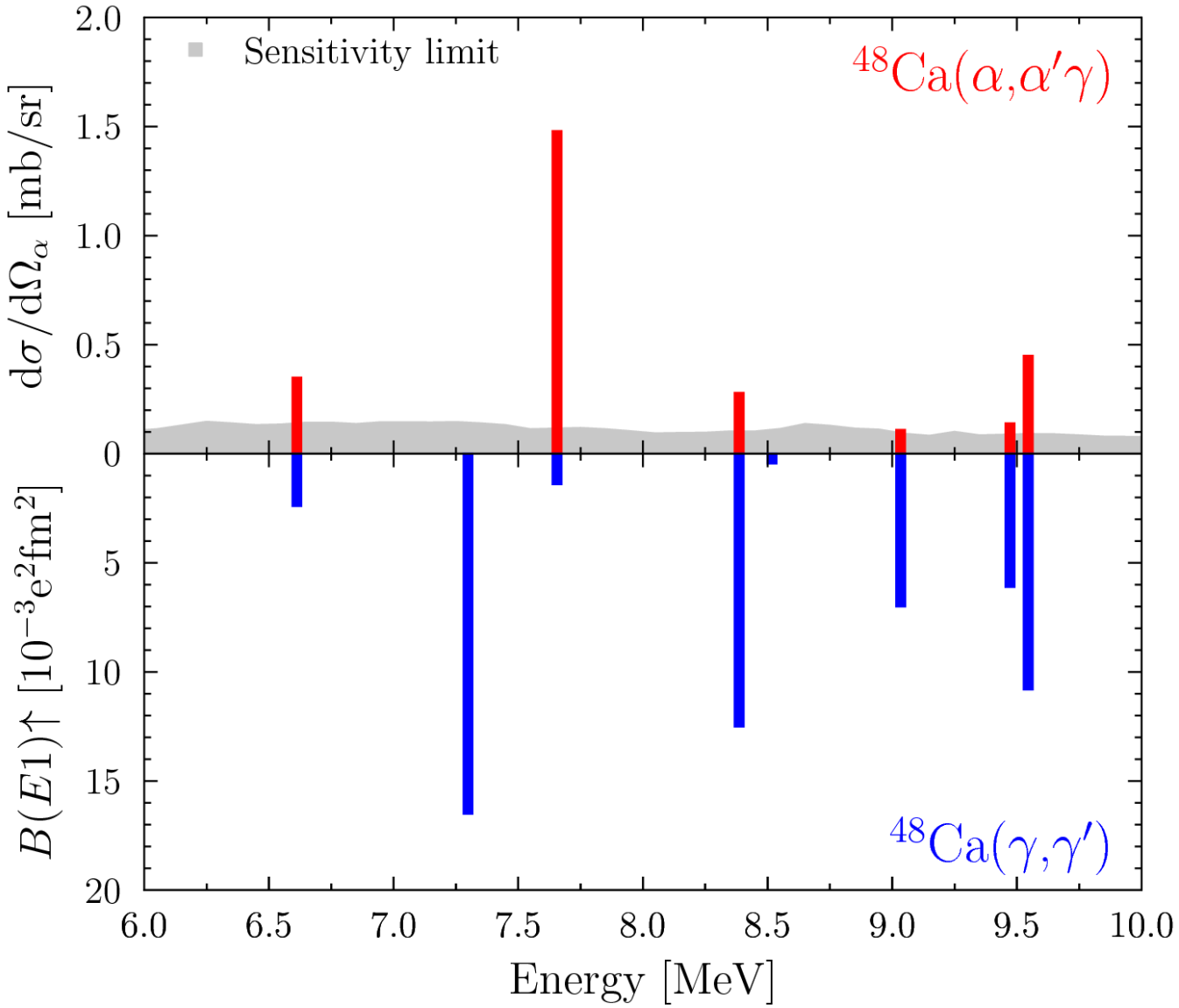
- Parity Measurement at the HIγS facility
- 7 dipole excitations were observed





➔ The excited dipole states have negative parity

J=1$^-$ states in (α,α′γ) and (γ,γ′)



Summary

- Extension of the systematic study in (γ,γ') and $(\alpha,\alpha'\gamma)$ experiments by the nucleus ^{94}Mo
- Determination of branching ratios possible

- Dipole excitations in ^{48}Ca have been measured with three different experimental methods
- Strong octupole contribution to the strongest dipole excitation by α particles excluded
- Parity of the state excited by photons but not excited by α particles could be determined as negative

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